

Regional climate consequences of large-scale cool roof and photovoltaic array deployment

Dev Millstein
Surabi Menon

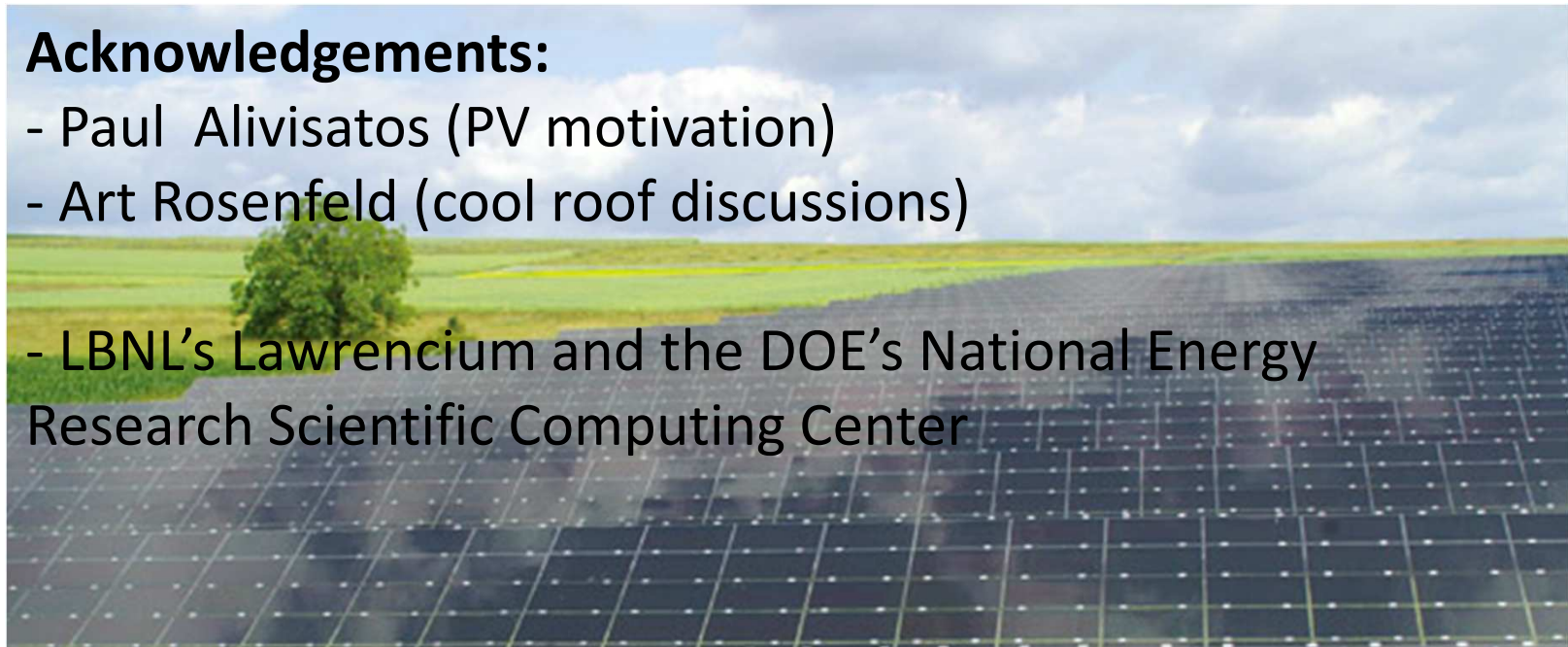


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Acknowledgements:

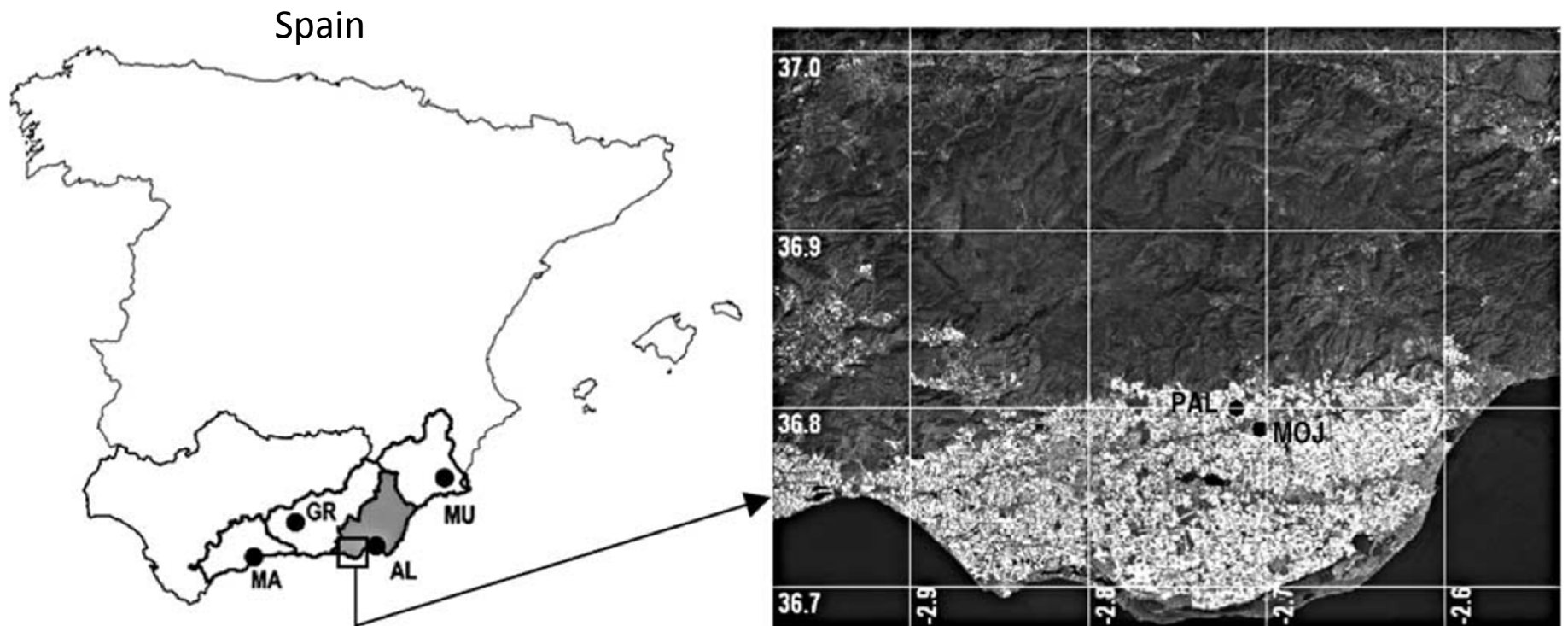
- Paul Alivisatos (PV motivation)
- Art Rosenfeld (cool roof discussions)
- LBNL's Lawrence Livermore and the DOE's National Energy Research Scientific Computing Center



Outline

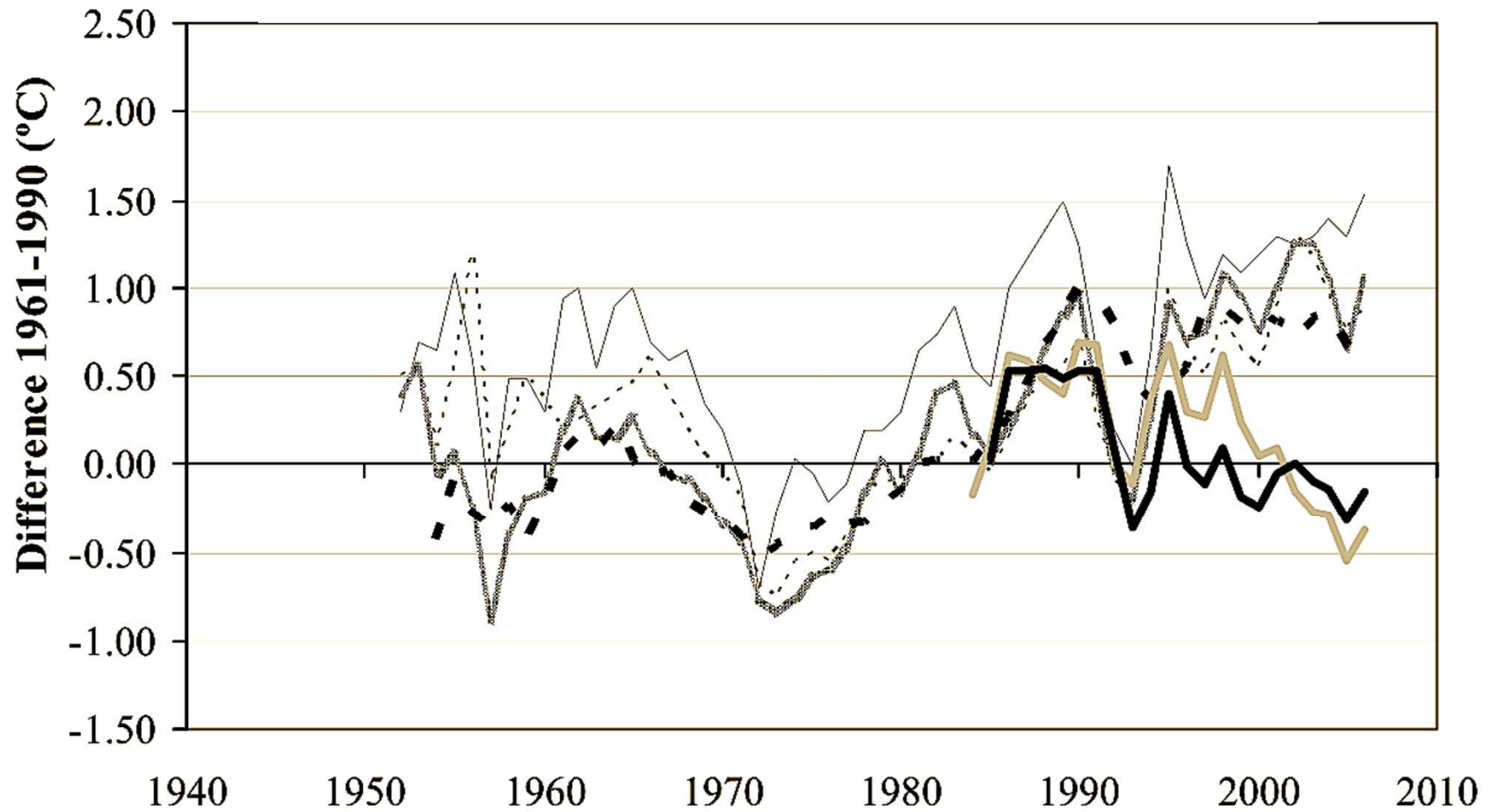
- Cool roofs: Observations vs. Modeling
 - Large-scale deployment
- What's new here → Modeling system
 - Feedbacks to atmosphere
- Findings
 - Cool roof and cool pavements
 - Desert photovoltaic power plants

The Province of Almeria



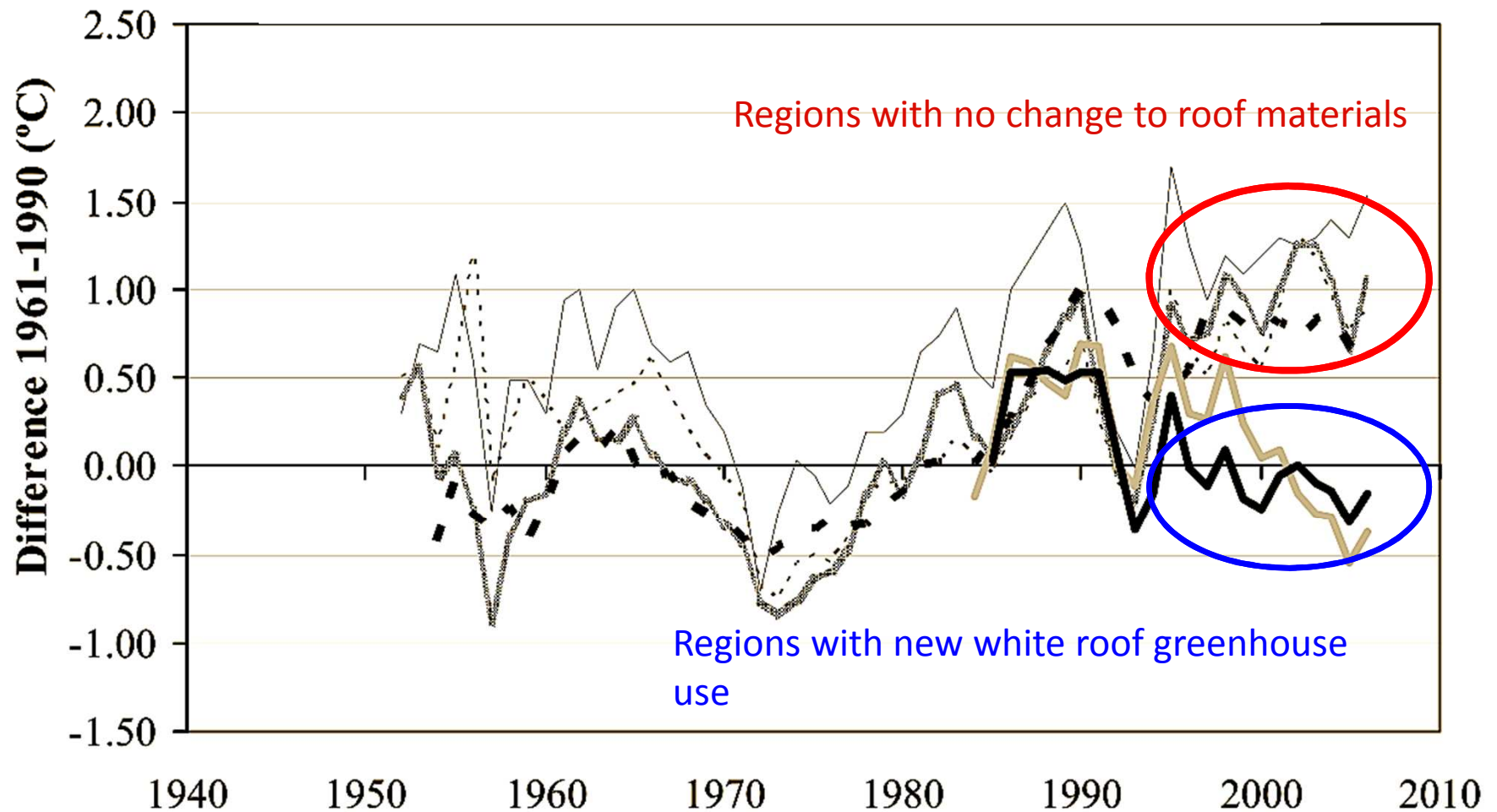


Annual surface temperature by region



Campra et al. (2008)

Annual surface temperature by region

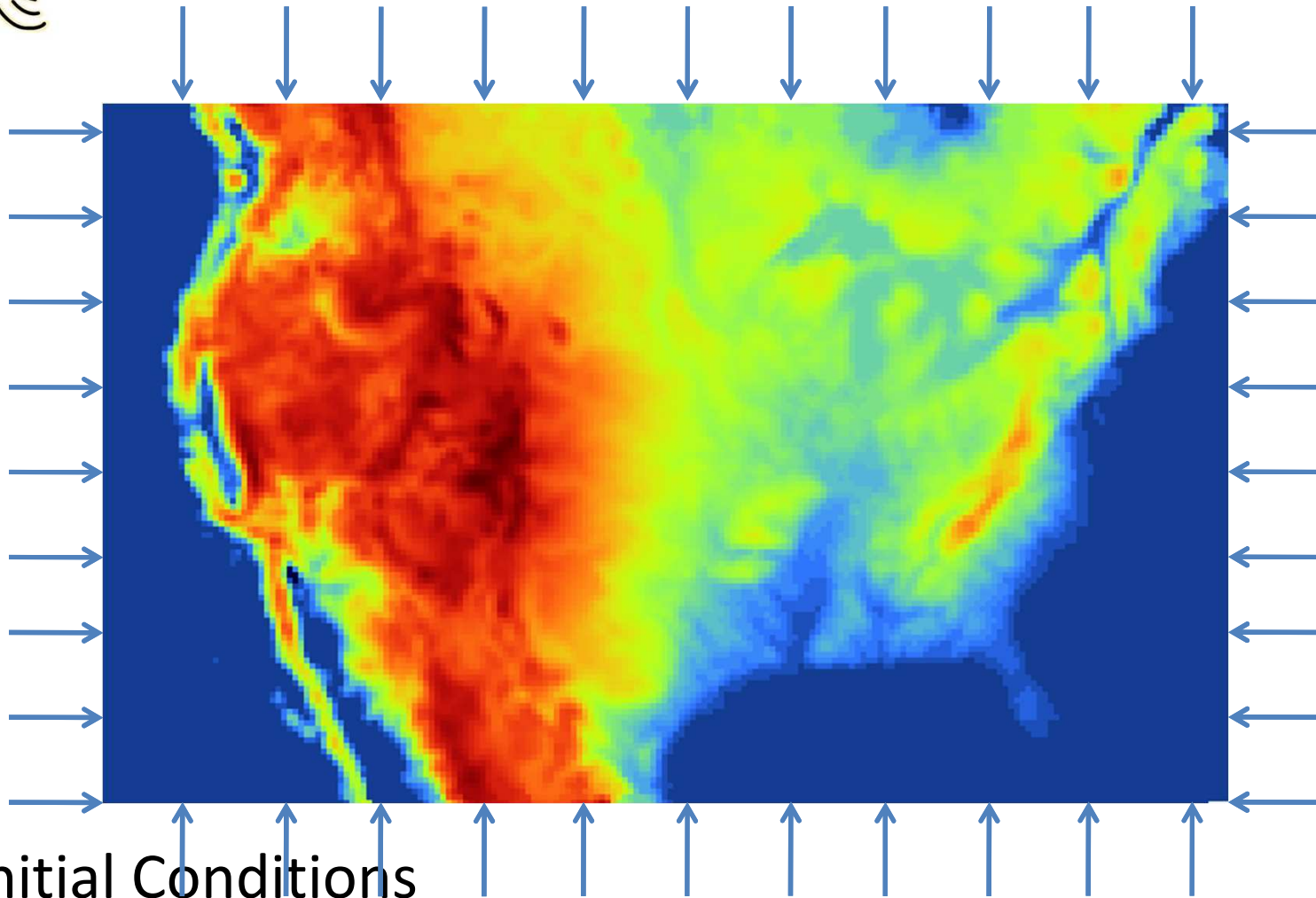


Observations vs. Models

- $\sim 1^{\circ}$ C reduction in temperature observed
- Similar temp. reductions from models
 - ✓ 1-2 $^{\circ}$ C reductions at 6 CA urban areas (Taha 2008)
 - ✓ Roughly similar modeling results found in studies at Athens (Synnefa et al 2008), and New York (Lynn et al 2009)
- Can we assume the same result everywhere?
 - Even over a large domain, and long time period?



Regional Climate Model



- Initial Conditions
- Continuously updated boundary conditions
(Winds, pressure, water, temperature)

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Abstract



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GREEN BUILDING: 'Cool roofs' found in Dallas (Wednesday, July 27, 2011)

Colin Sullivan, E&E reporter

Wondering if a "cool roof" would save you money? The question depends largely on where you live.

Scientists at the Lawrence Berkeley National Laboratory found that the energy use to which energy use is trimmed depends largely on where you live.

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Efficacy of Cool Roofs Varies from City to City

New Berkeley Lab study investigates climate consequences of cool roofs and large-scale solar panel deployment.

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- ▶ Pinpointing geothermal energy's water needs
- ▶ Maldives crowdsources 2020 carbon-neutral plan
- ▶ Map identifies potential areas for boosting biofuel crop yield
- ▶ Carbon capture progress has lost momentum, says energy agency
- ▶ Lake water checks come under

NEWS

Jul 14, 2011

Cool roofs affect climate

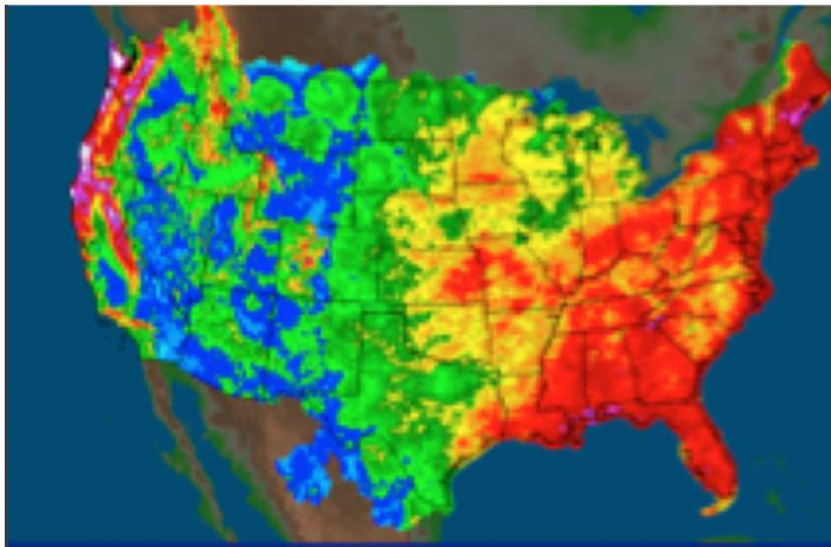
Changing the surface reflectivity of urban areas could have a significant impact on regional climate, according to researchers at Lawrence Berkeley National Laboratory (LBNL) in the US.

Dev Millstein and Surabi Menon investigated, on a continental scale, the

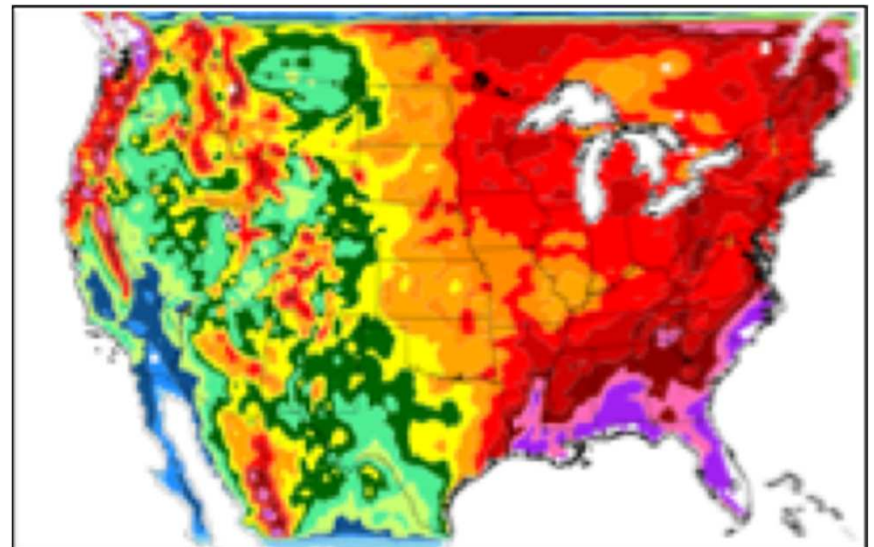
Bringing
science solutions
to the world

How well does the model do?

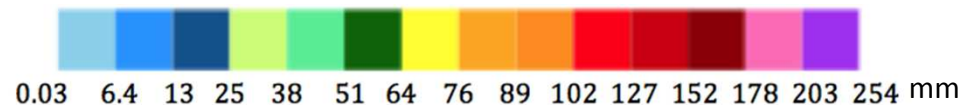
- Temperature (can capture ~55% of the variance)
- Precipitation



Observations

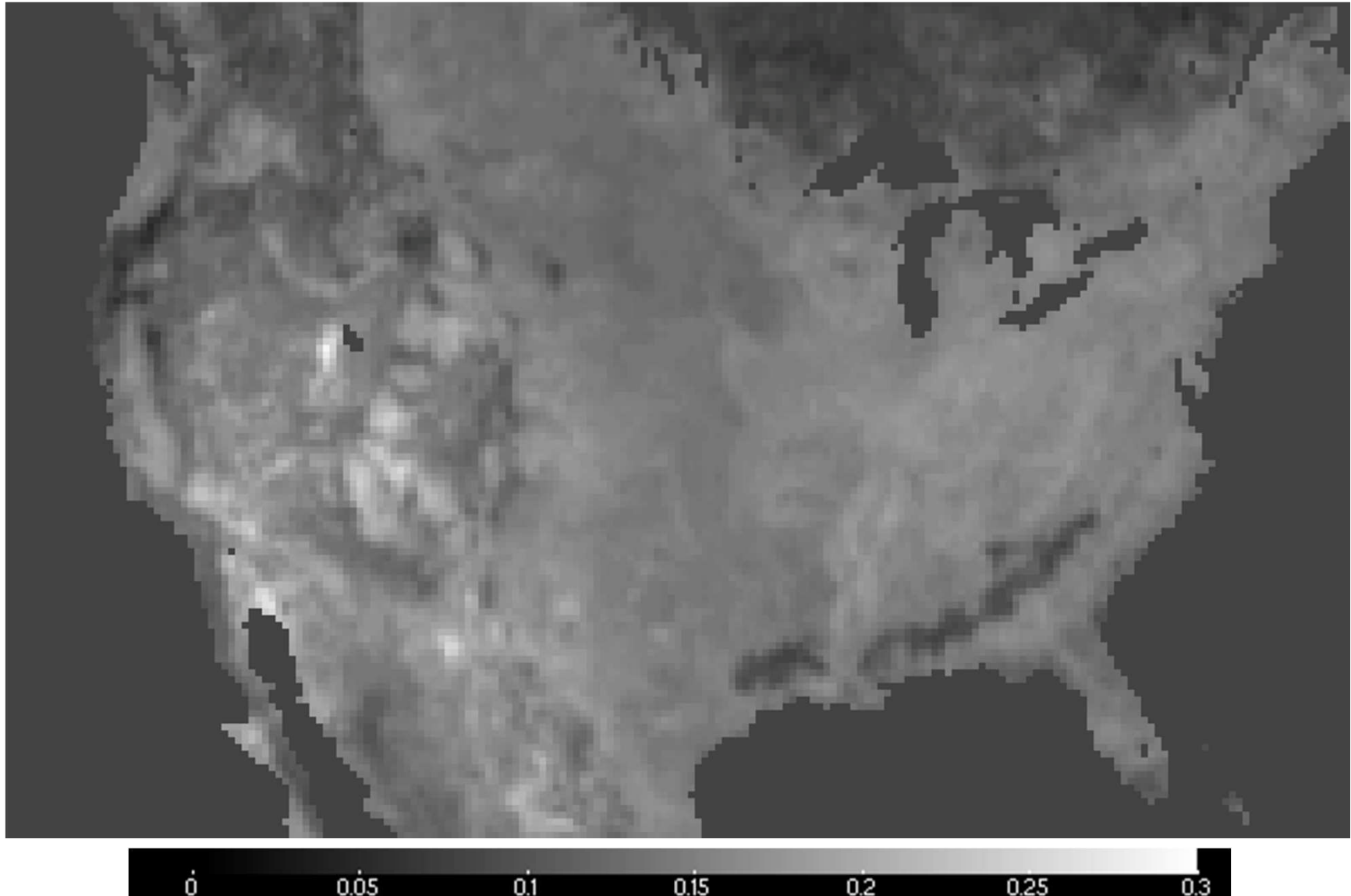


Model

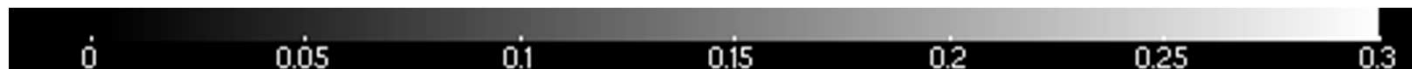
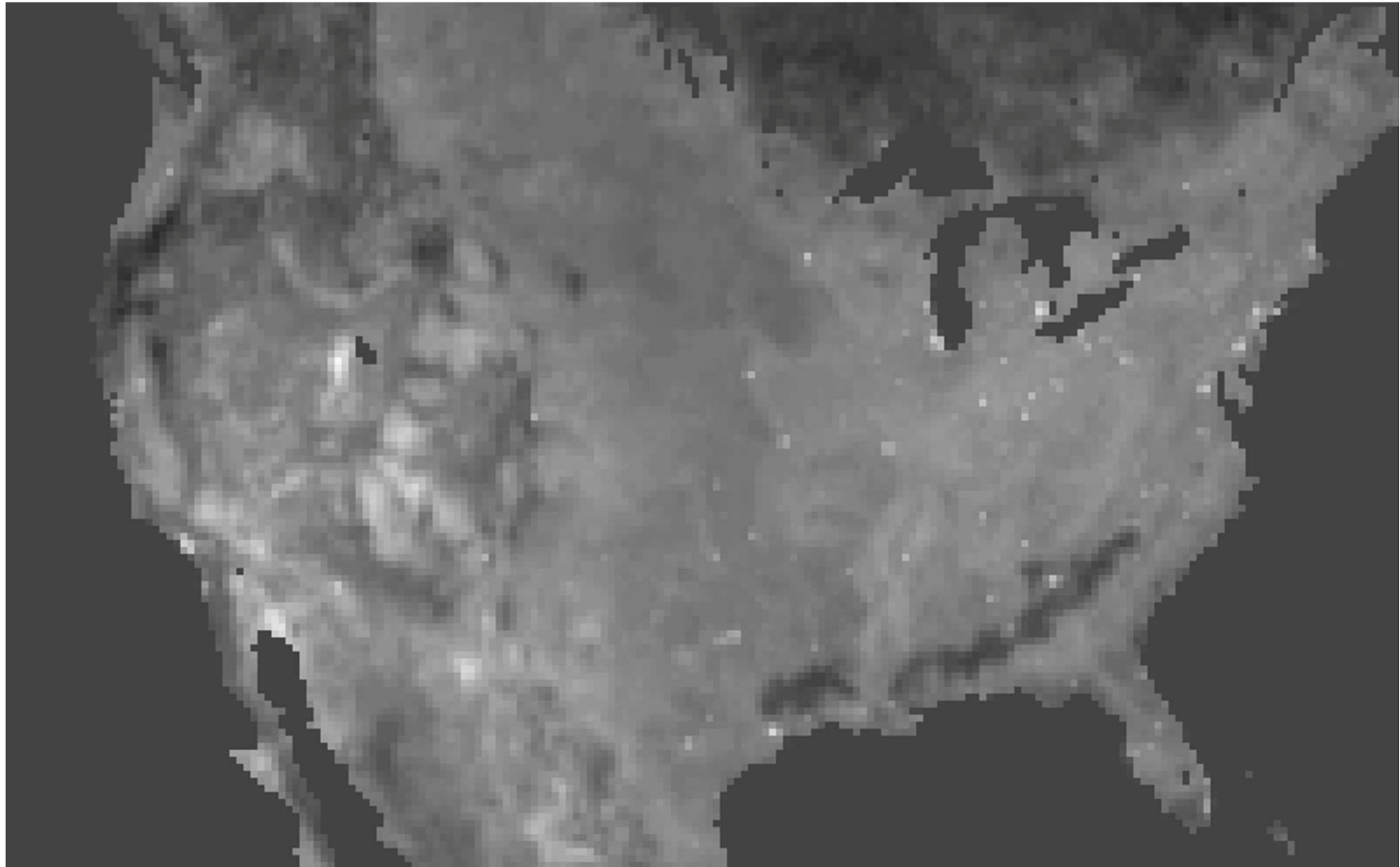


- Observations based on radar and gauge measurements (NWS)
- Comparison is accumulated rainfall over the year 2005

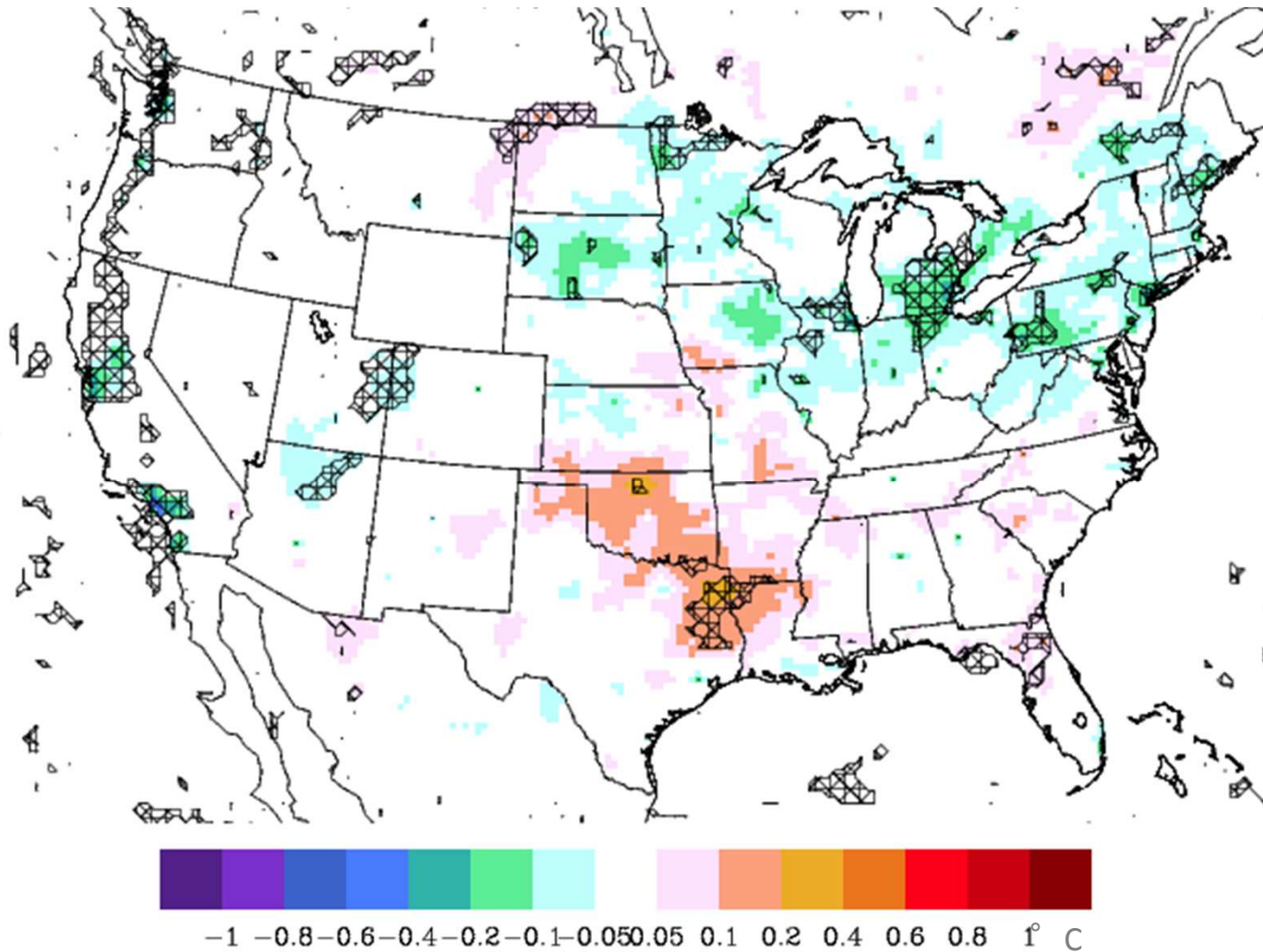
Surface reflectivity



Surface reflectivity



Temperature change from cool cities



- Averaged over 12-years (1 pm PST)
- Hatched areas: significantly different from no change (95% C.I.)

Temperature change from cool cities

Location	% Urban ^a	Δ Albedo	Summer (JJA)	Winter (DJF)
			Δ Temperature	Δ Temperature
Columbus, OH	20%	0.02	−0.02*	−0.05
San Antonio, TX	27%	0.03	−0.08*	−0.10
San Diego, CA	28%	0.03	−0.13	−0.11
Jacksonville, FL	28%	0.03	+0.01*	−0.06
San Jose, CA	29%	0.03	−0.23	−0.10
Dallas, TX	42%	0.05	−0.09*	−0.08*
Phoenix, AZ	47%	0.05	−0.16	−0.19
Miami, FL	54%	0.06	−0.11	−0.12
Chicago, IL	61%	0.07	−0.27	−0.12
Atlanta, GA	70%	0.08	−0.12	−0.21
Philadelphia, PA	75%	0.09	−0.22	−0.22
Houston, TX	86%	0.10	−0.19	−0.24
New York, NY	91%	0.10	−0.30	−0.24
Detroit, MI	95%	0.11	−0.39	−0.12
Los Angeles, CA	96%	0.11	−0.53	−0.41

* Indicates the temperature change is not significantly different from 0.

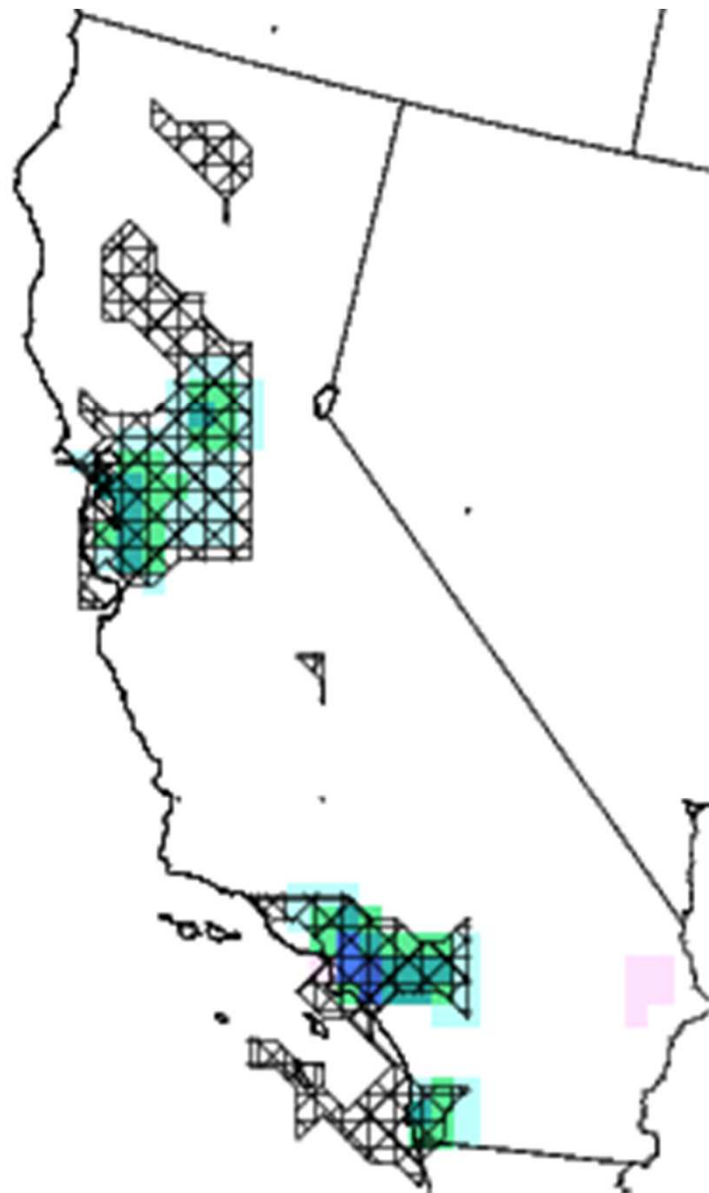
^a Percentage of land area classified as urban.

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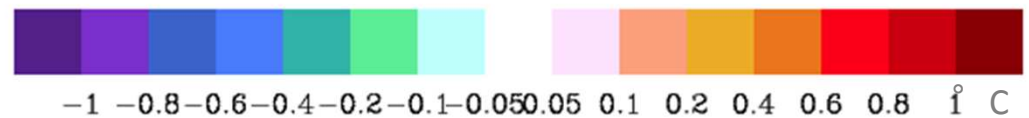
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California summer average temperature reductions:

- 0.2 – 0.3 ° C in most urban regions
- up to 0.6 ° C in Los Angeles
- No feedback issues



Equivalent carbon reductions

1 m² of cool surface = ??? avoided tons of CO₂

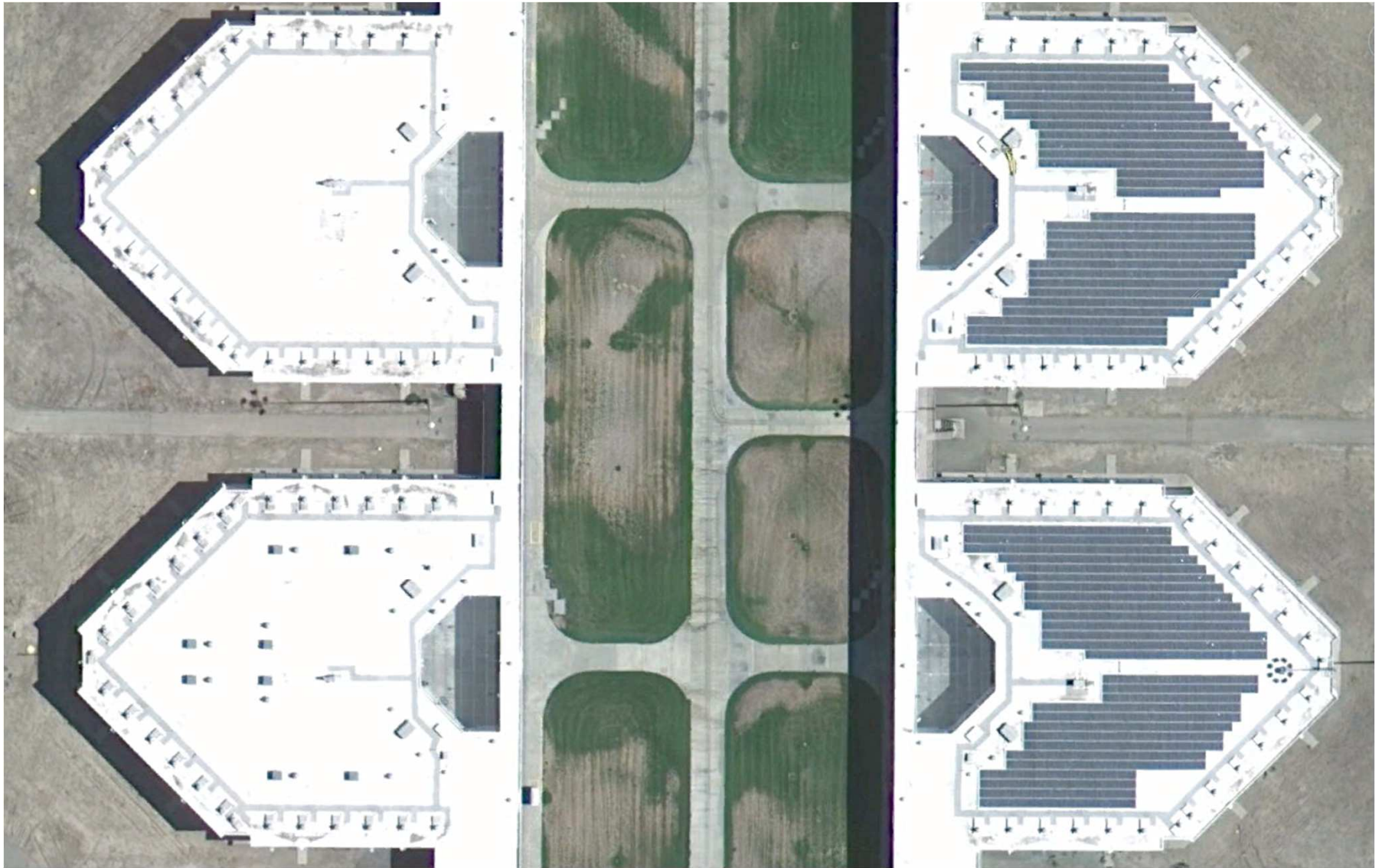
Assumptions:

- 0.91 kW t⁻¹ atmospheric CO₂ radiative change
 - Menon et al 2010, Akabari et al 2009
- 55% atmospheric retention of emitted CO₂
 - IPCC 2007

Equivalent carbon reductions

Cool roofs and pavements	Annual values
Increase to outgoing radiation	$0.16 \pm 0.03 \text{ W m}^{-2}$
CO ₂ per roof area	$175 \pm 33 \text{ kg CO}_2 \text{ m}^{-2}$
CO ₂ per pavement area	$125 \pm 33 \text{ kg CO}_2 \text{ m}^{-2}$
National Total offset	$3.3 \pm 0.5 \text{ Gt CO}_2$

Cool roofs vs. photovoltaic panels



Alameda County Jail (California)

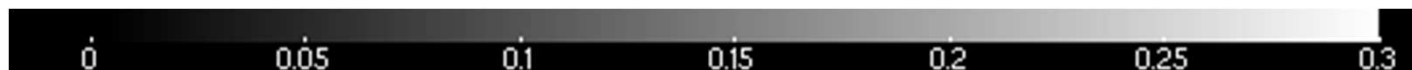
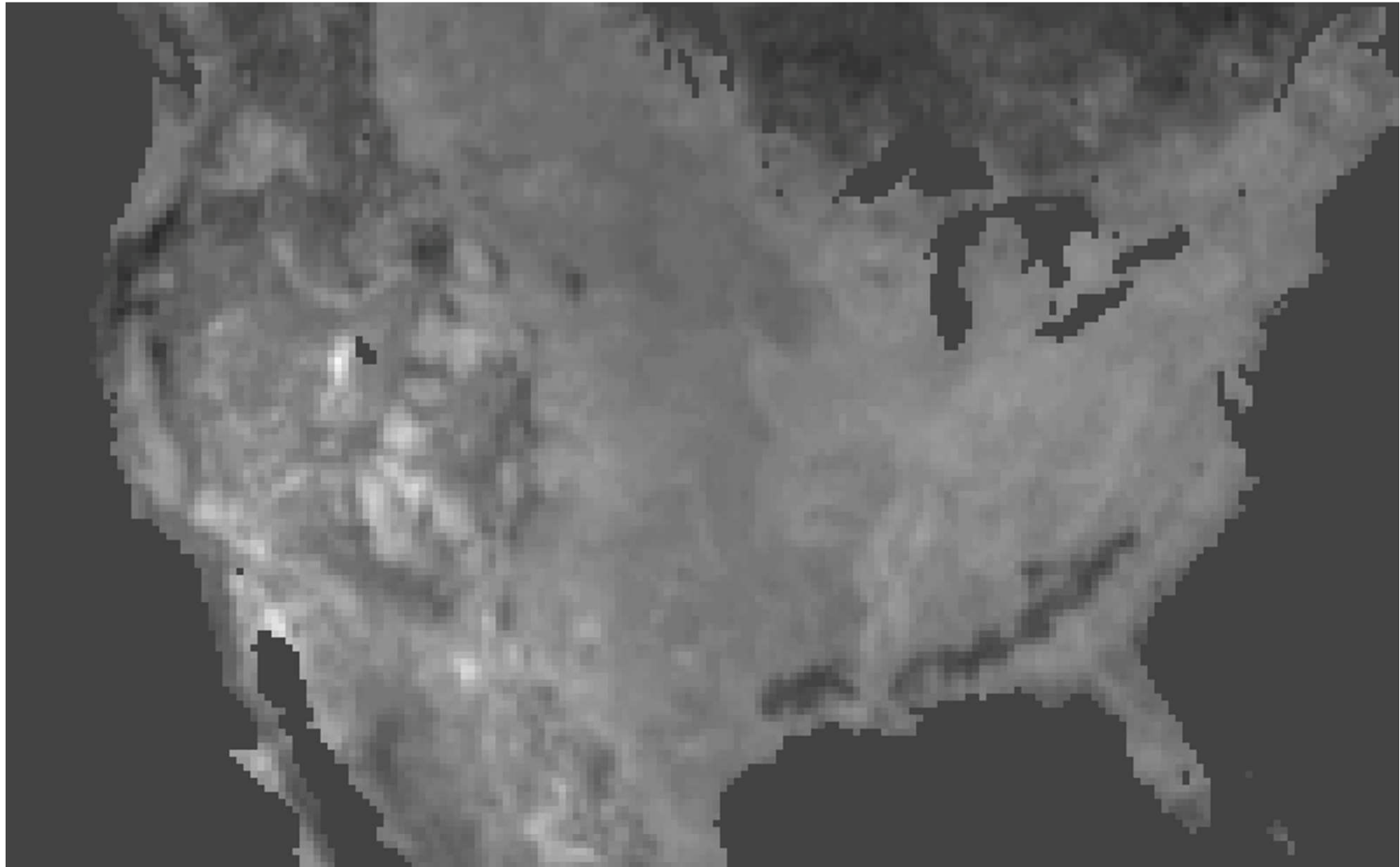
Nevada



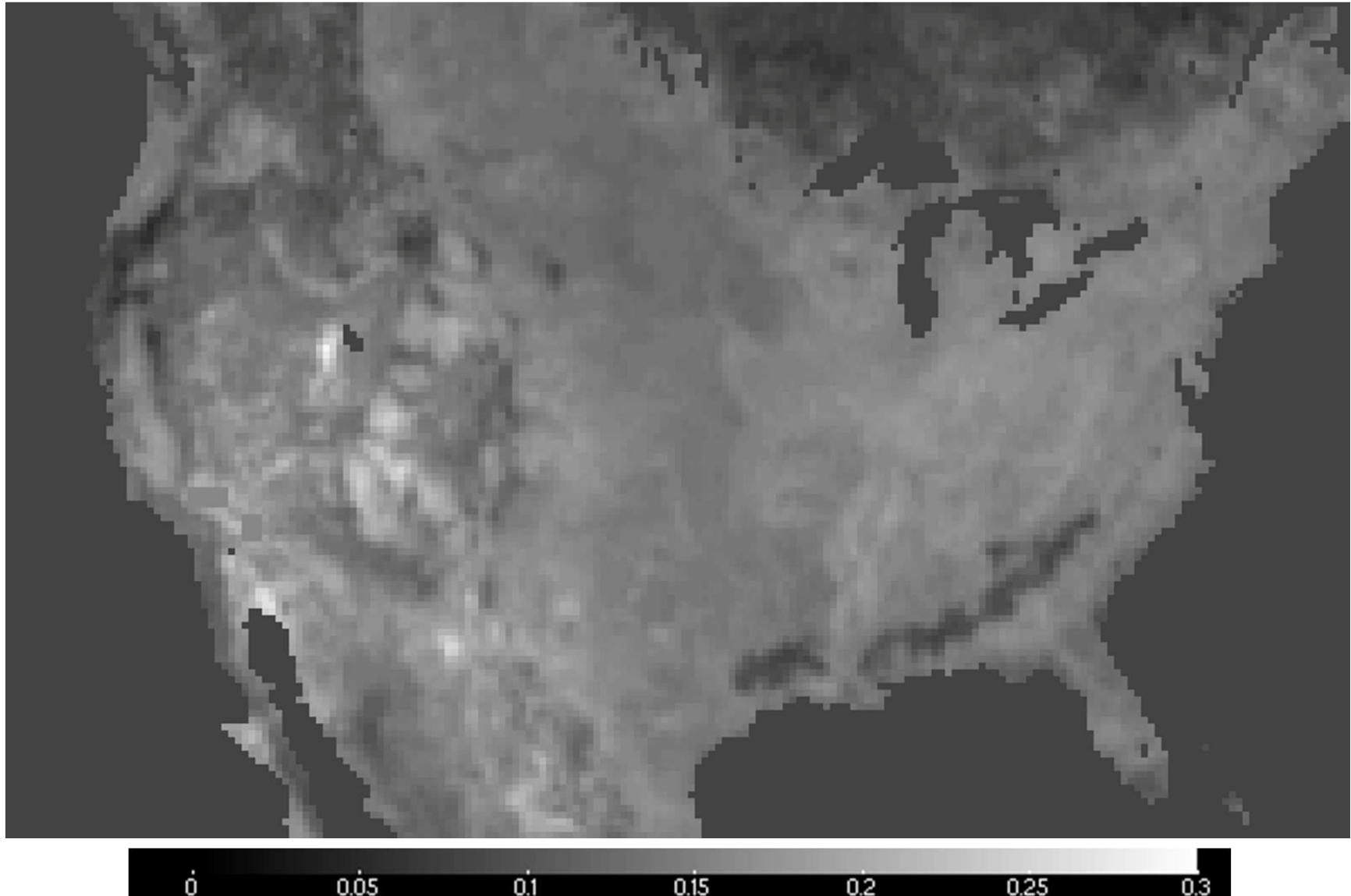
Ohio



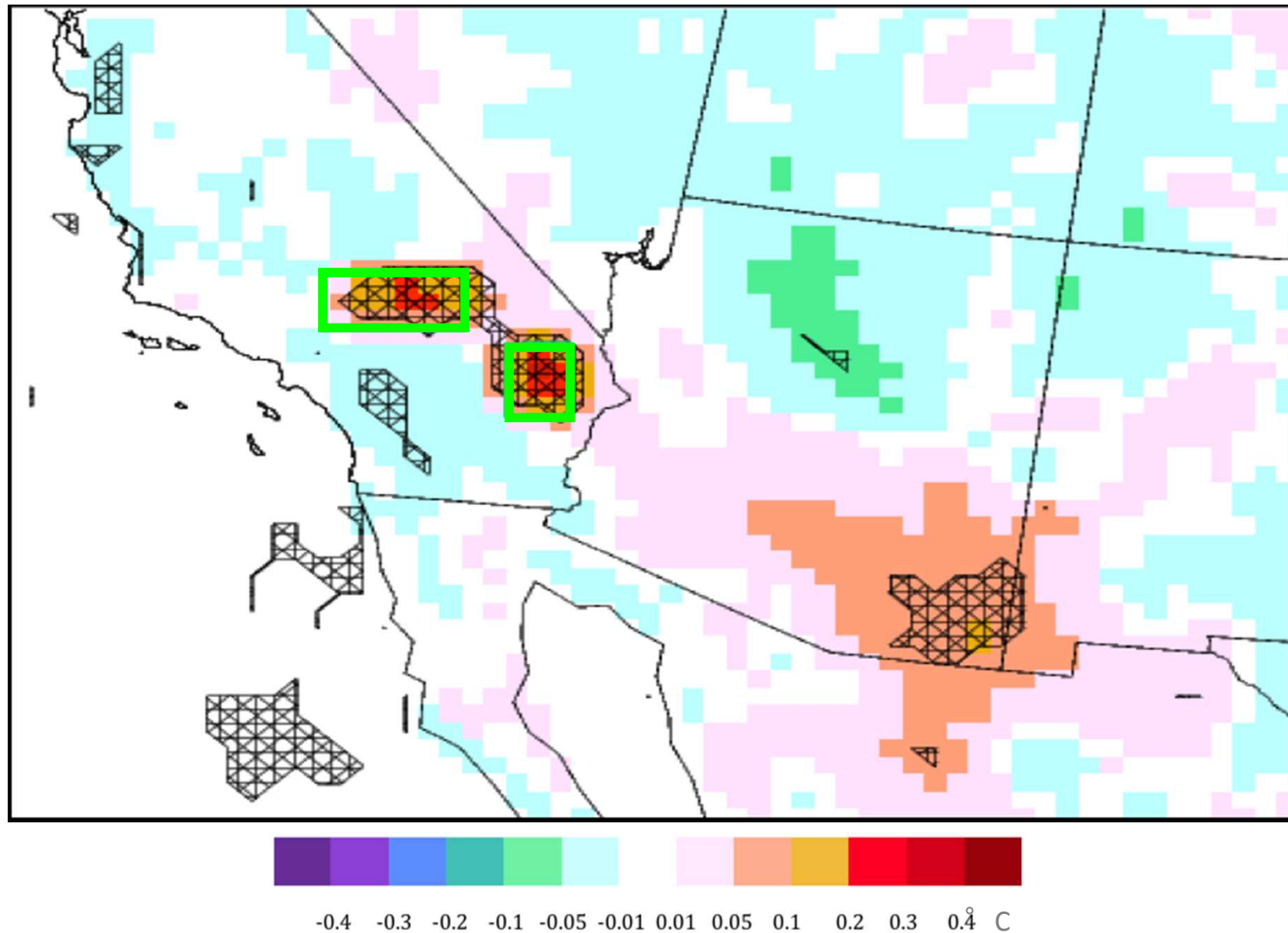
Surface reflectivity

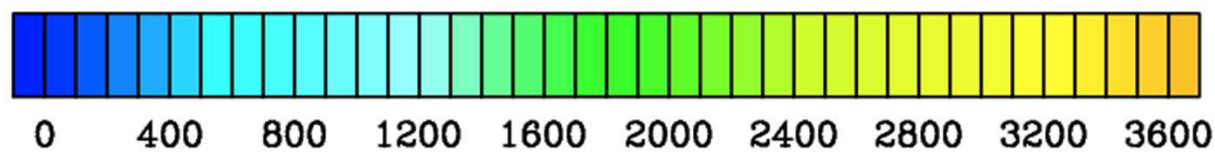
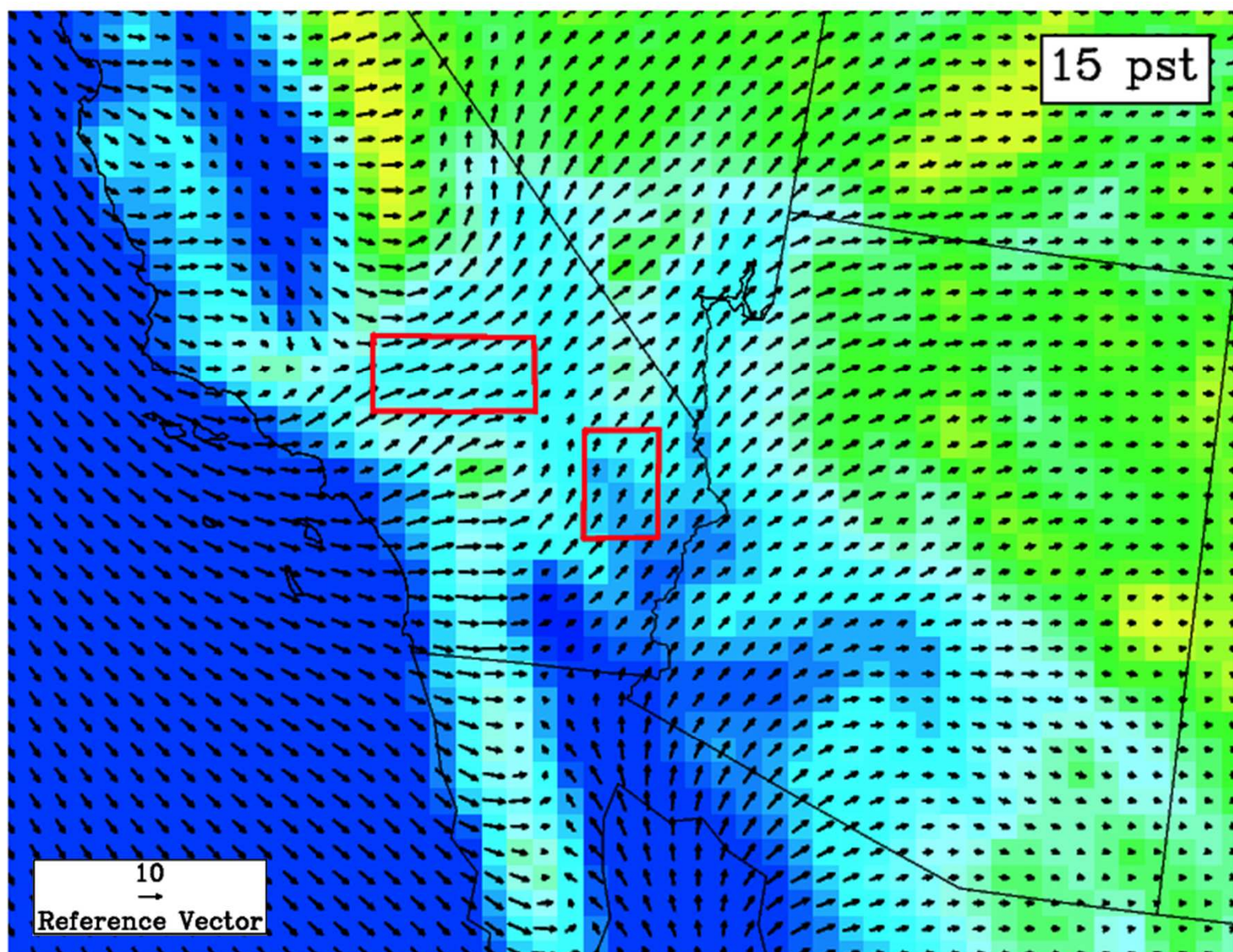


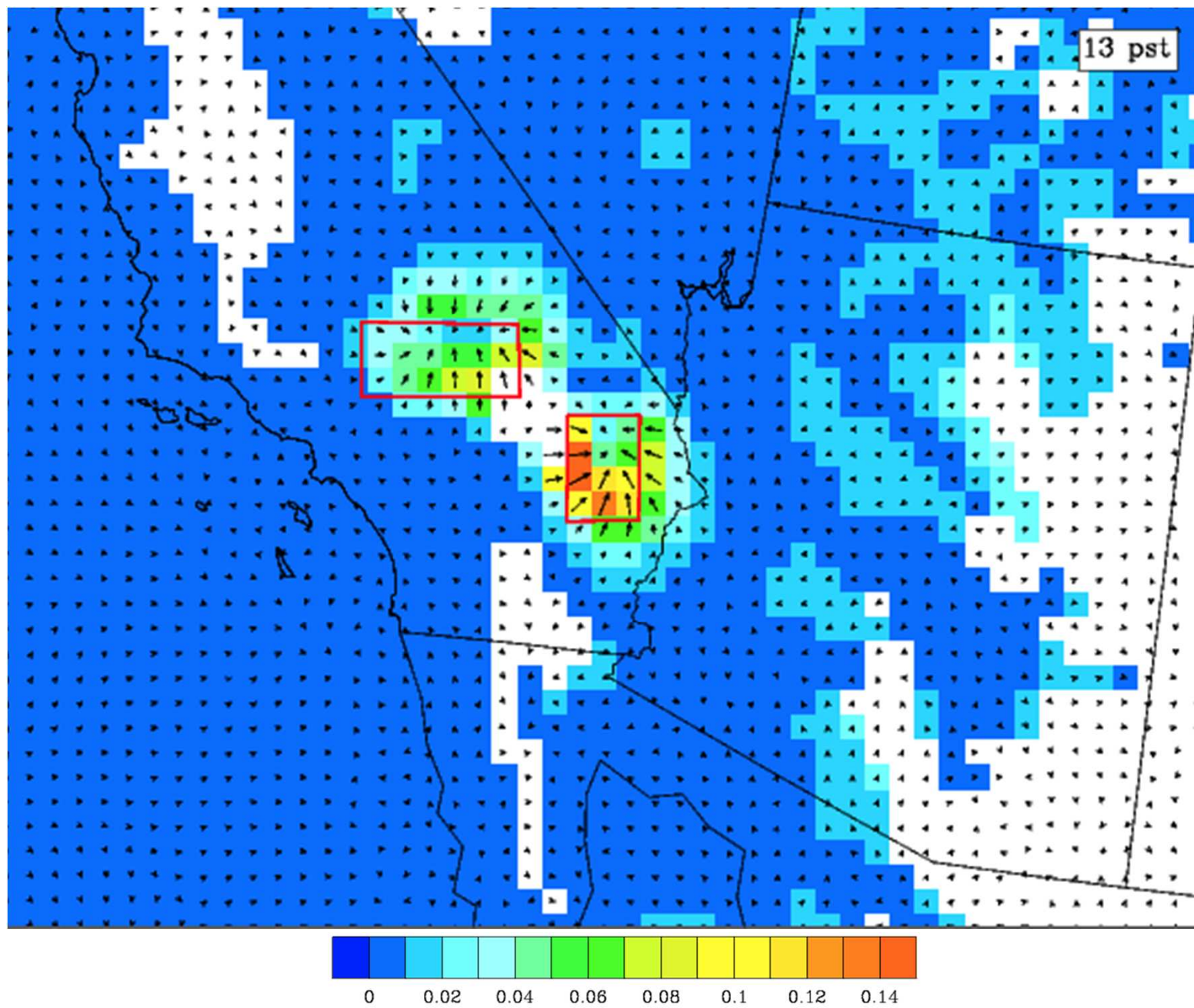
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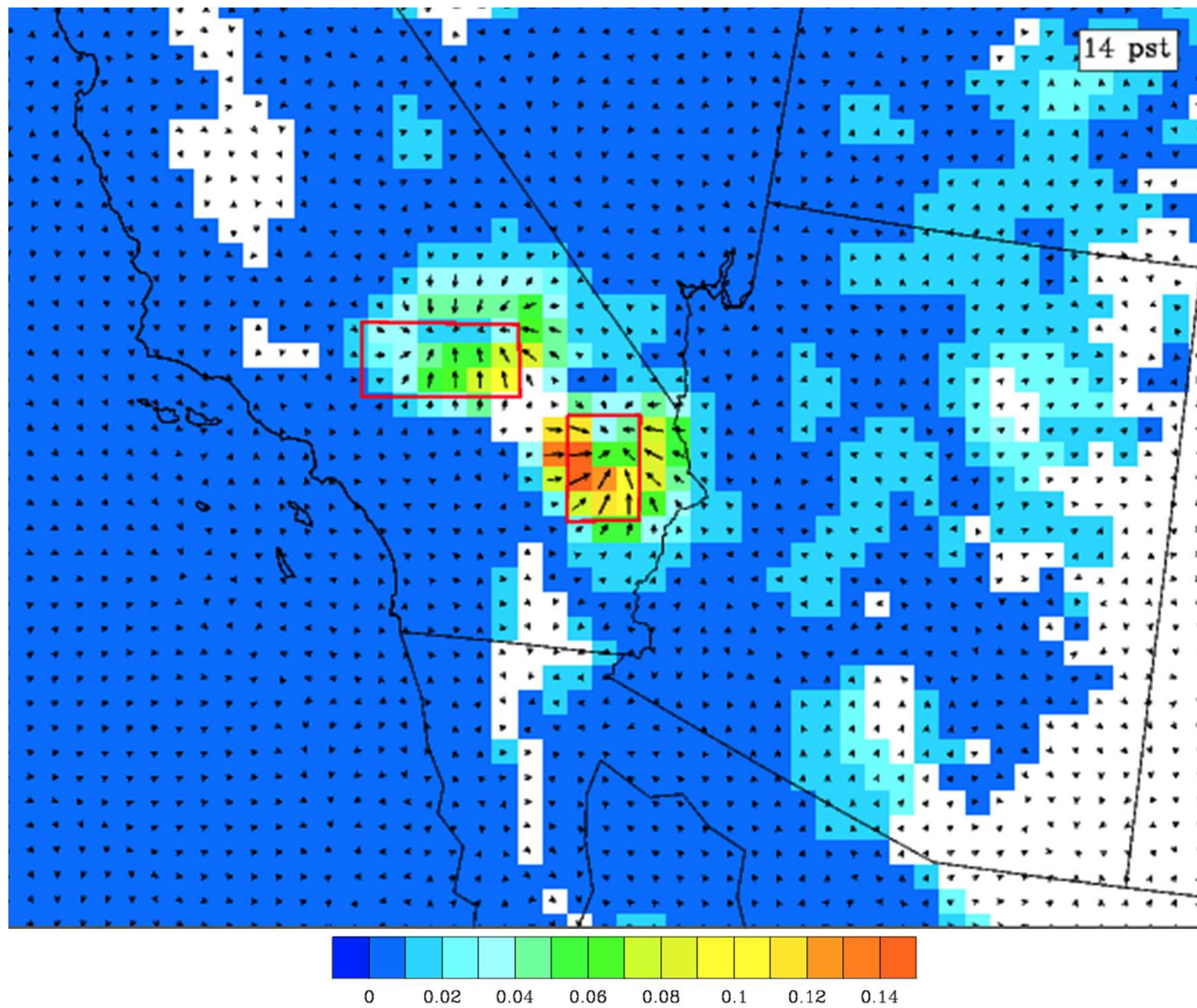


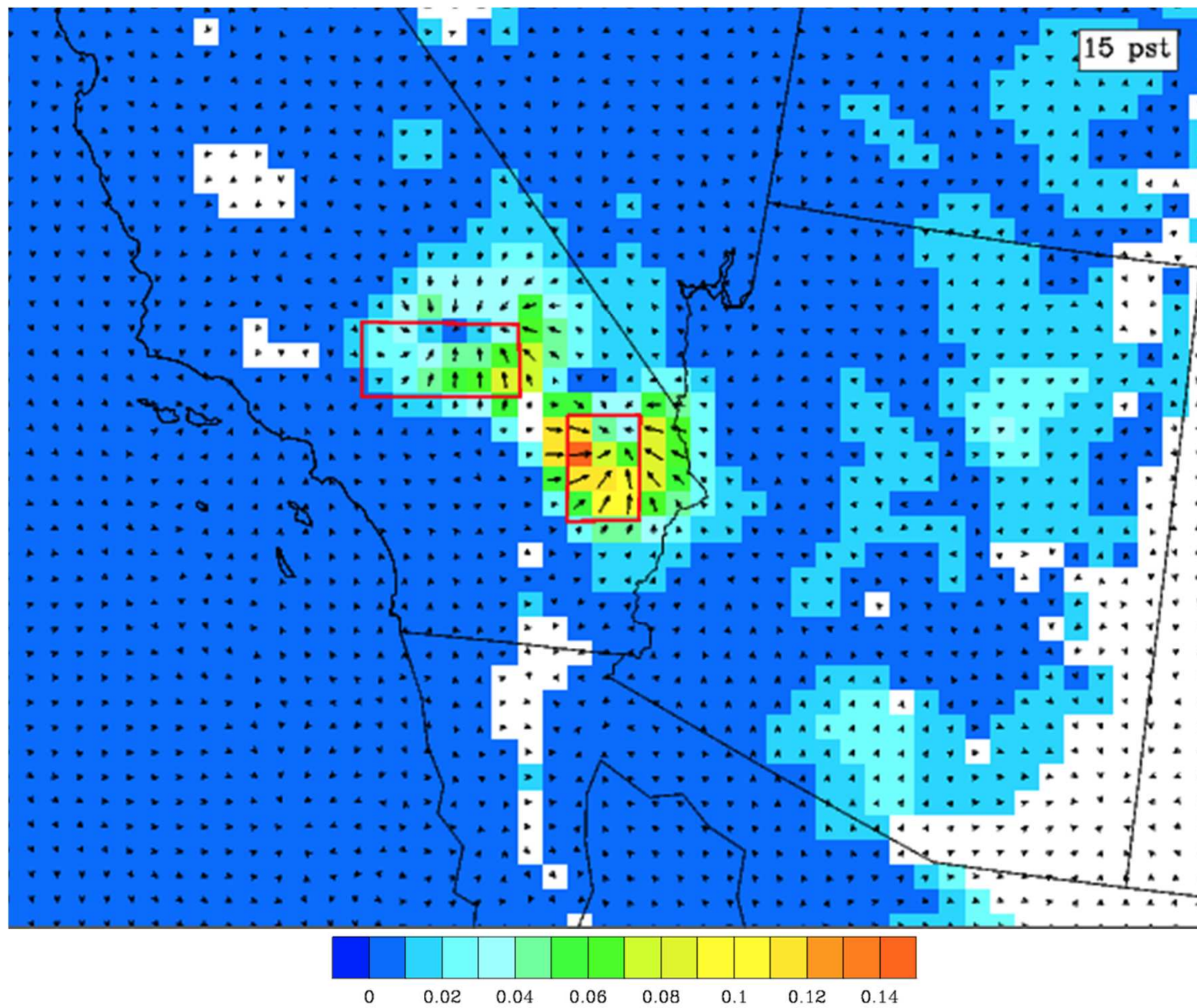
Temperature change from PV

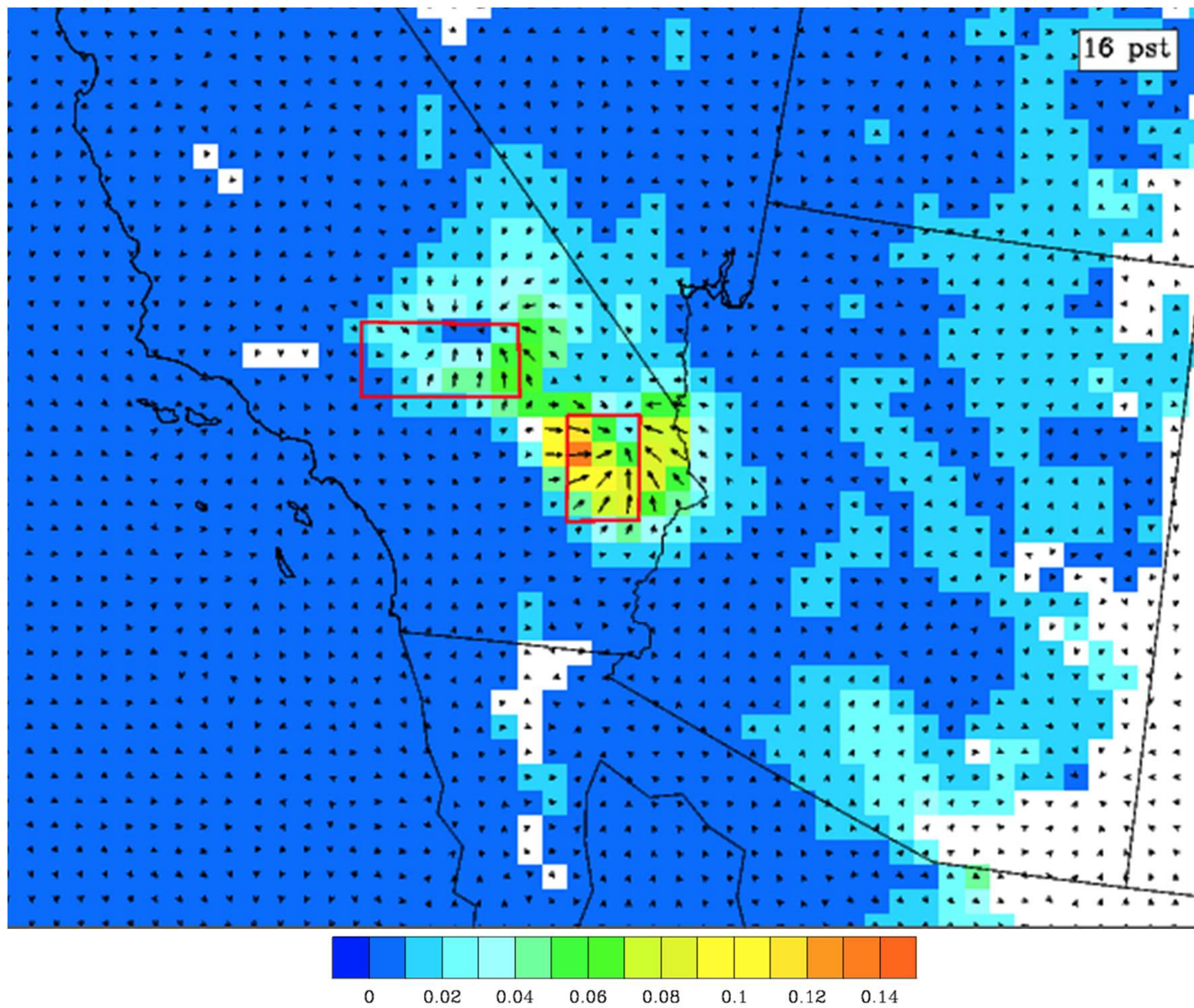


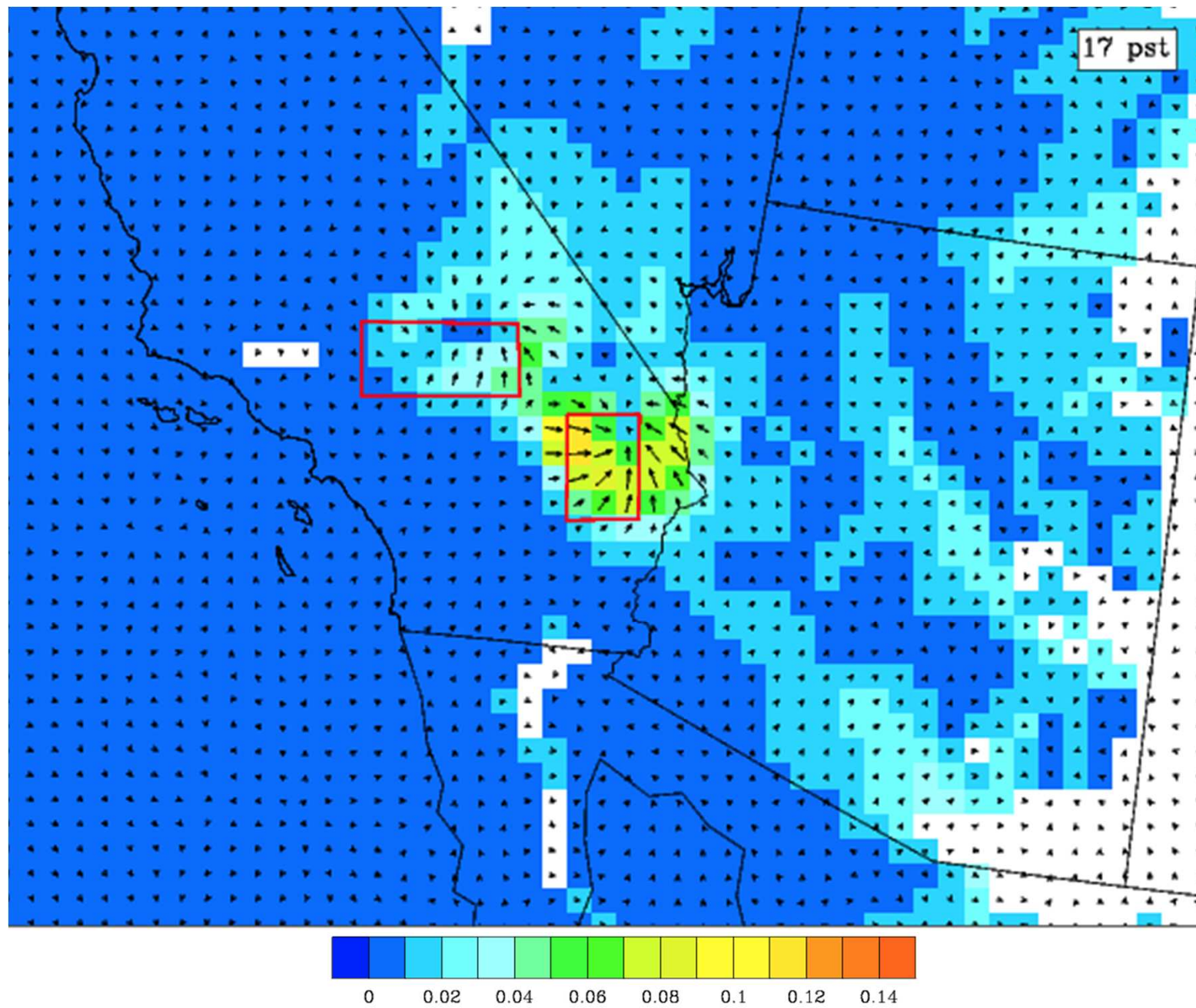


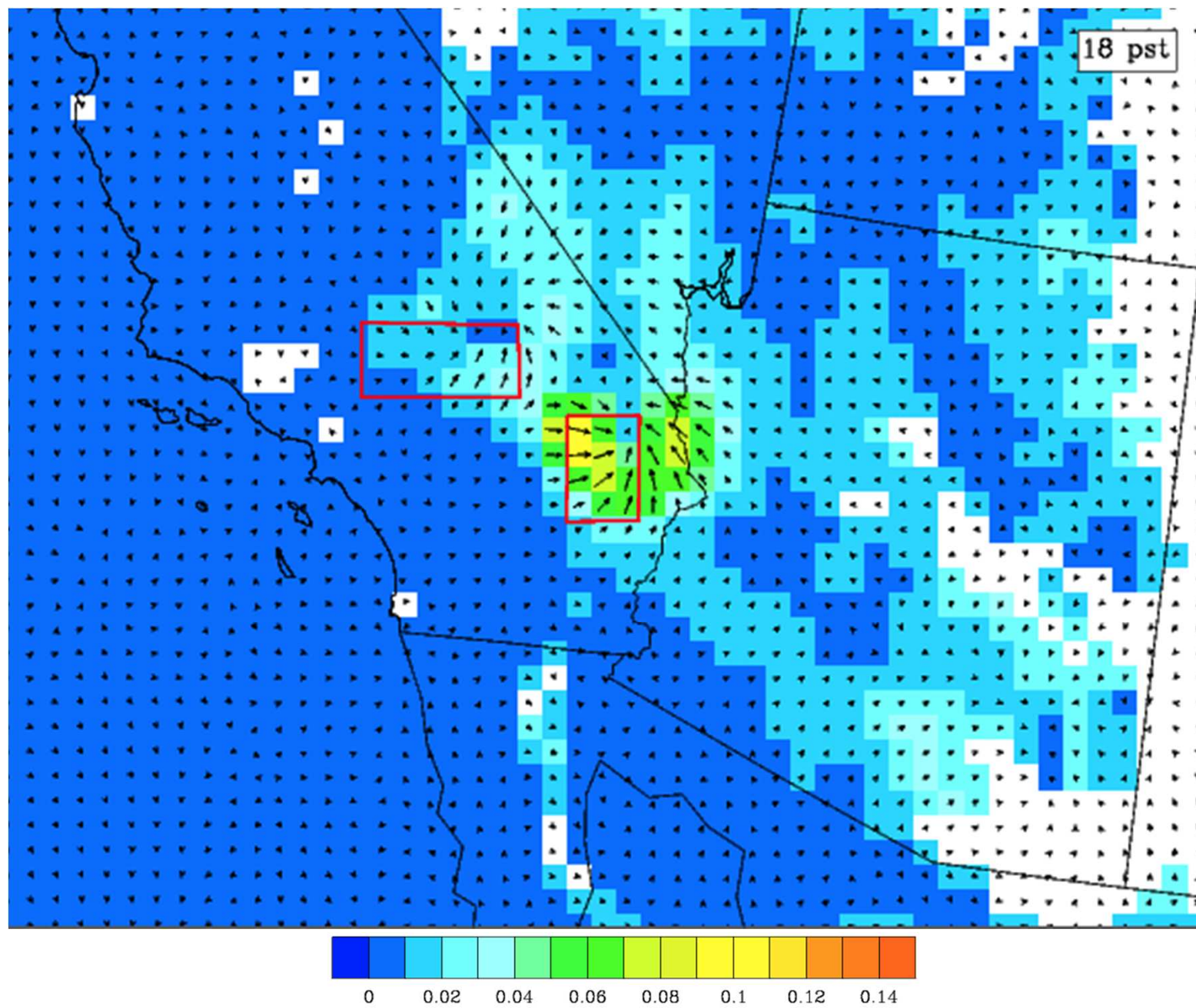


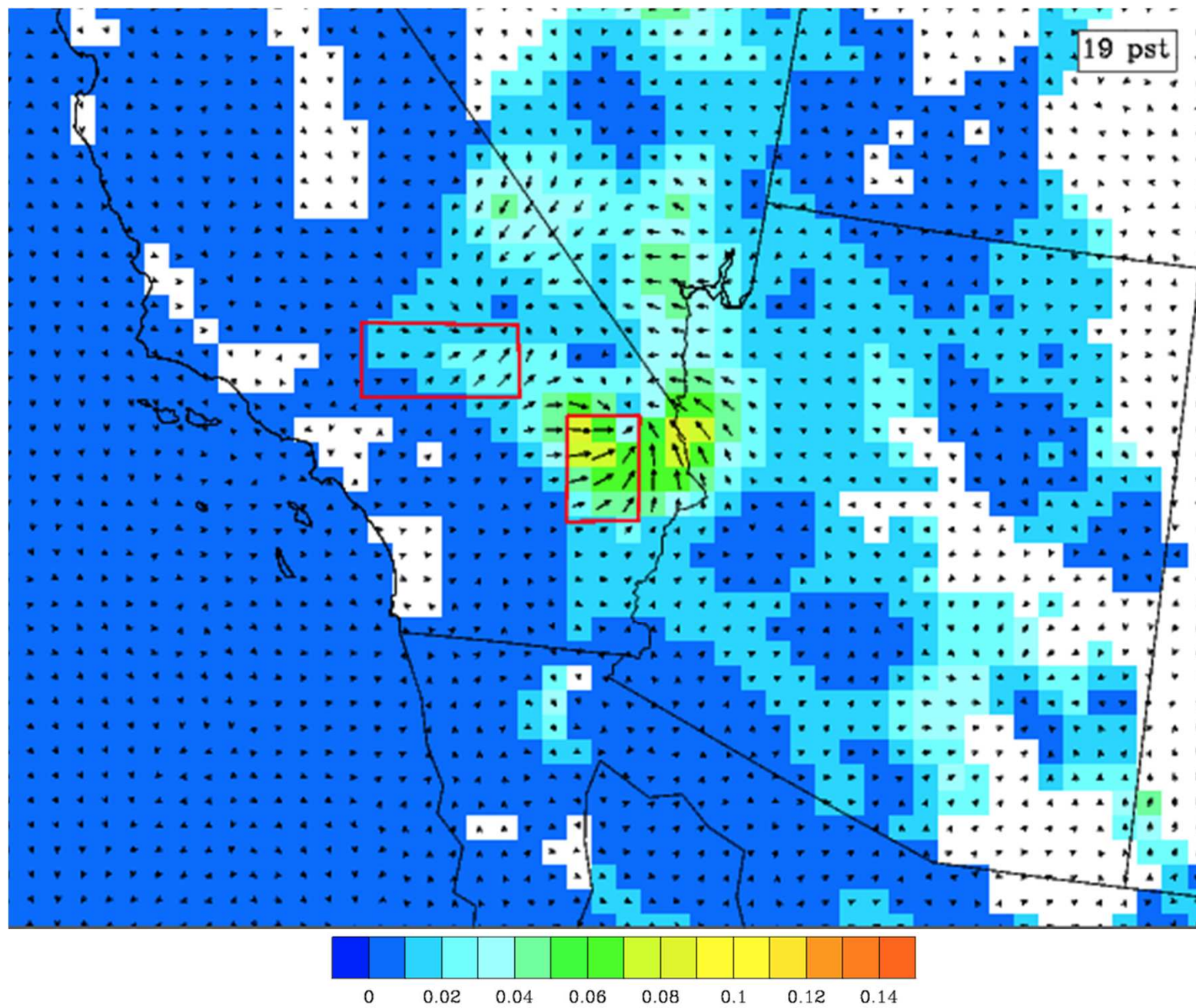


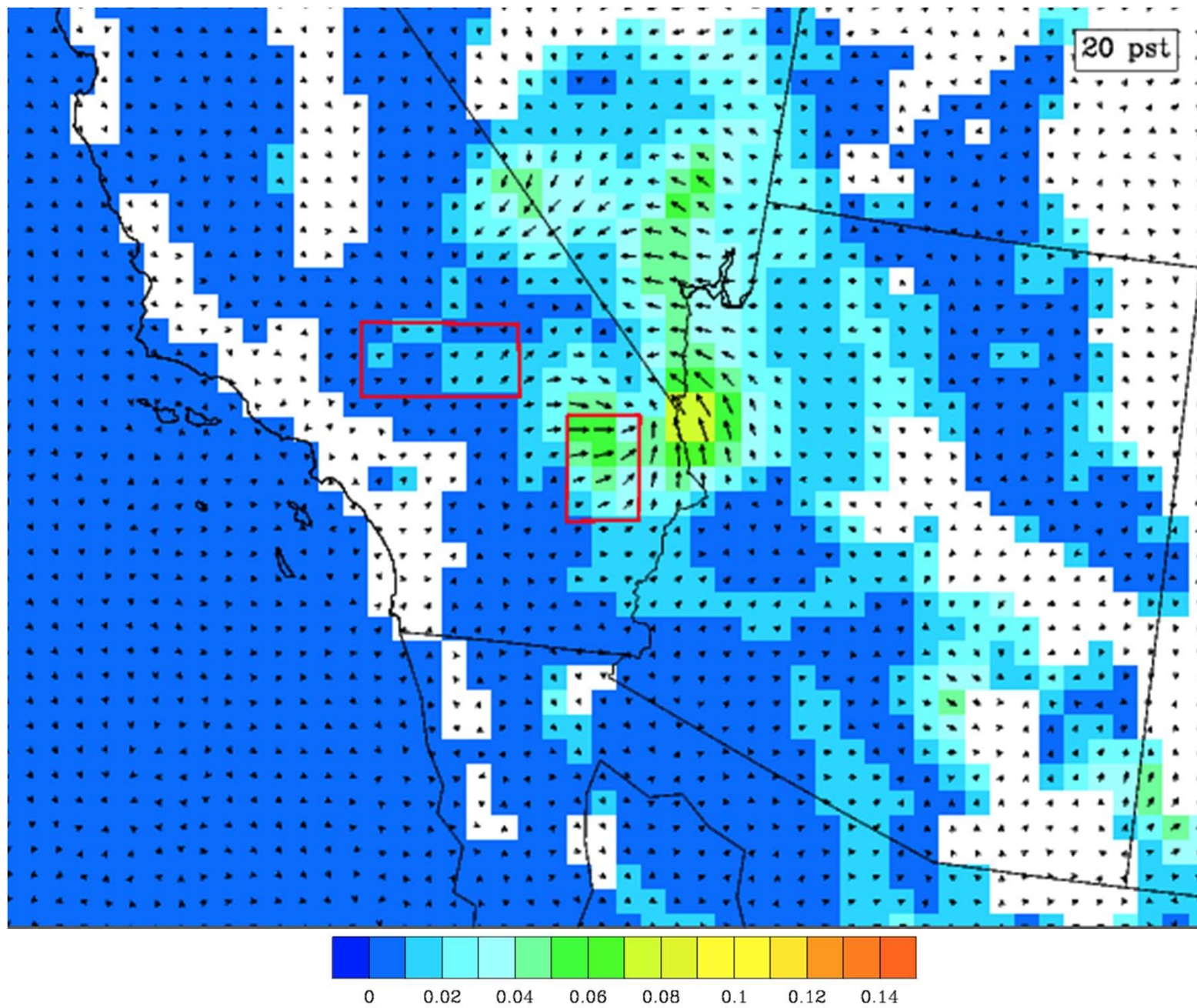


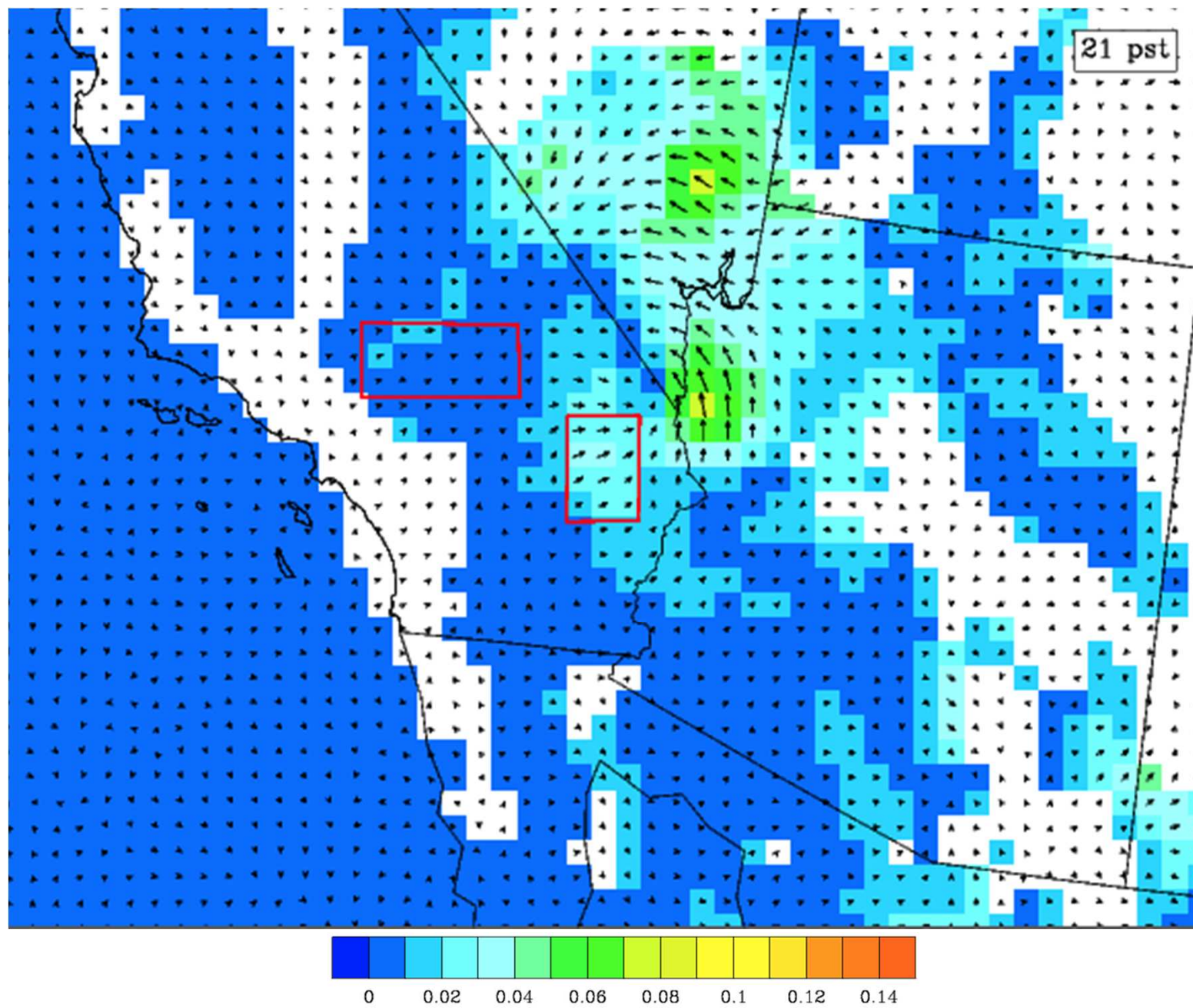


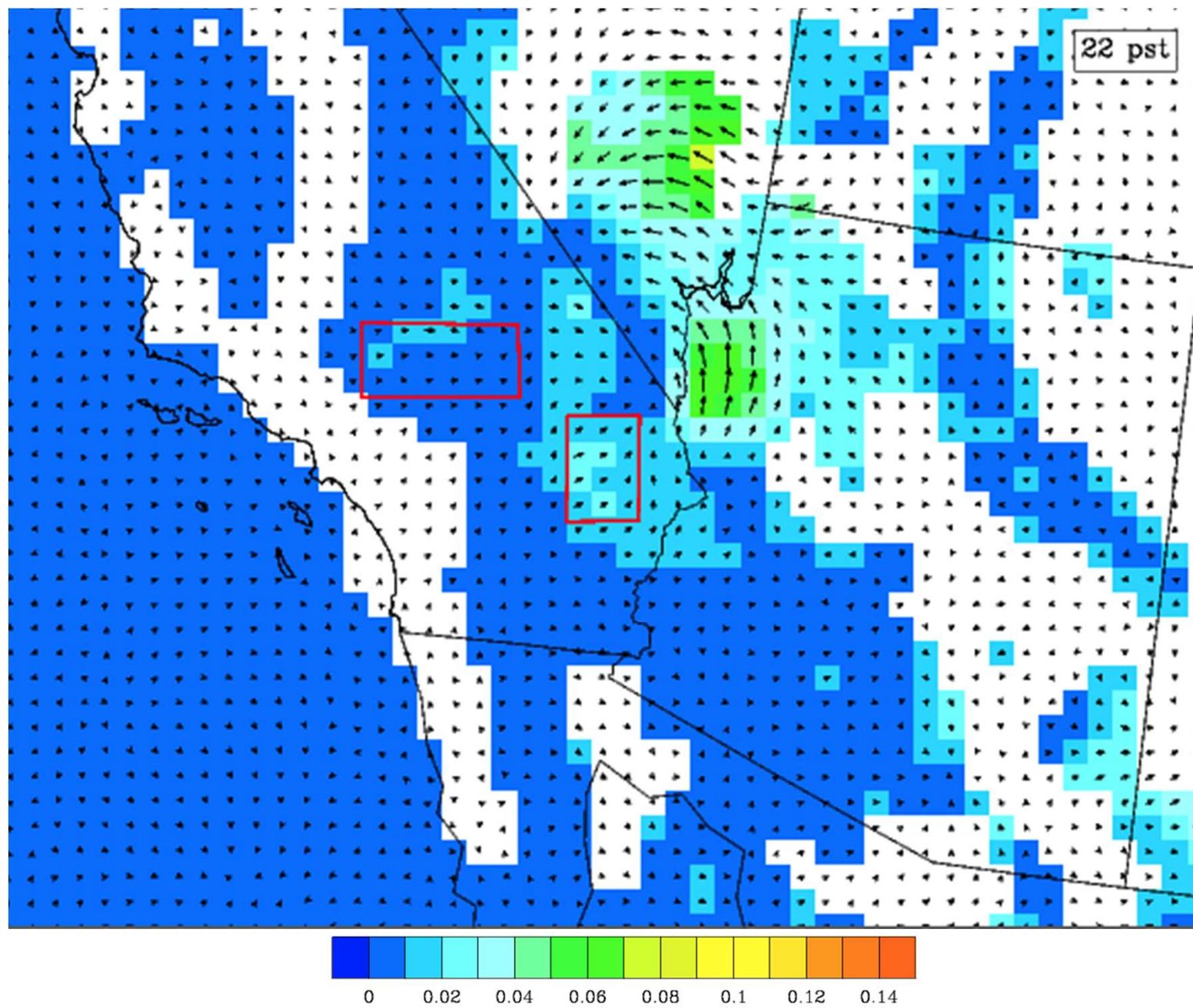


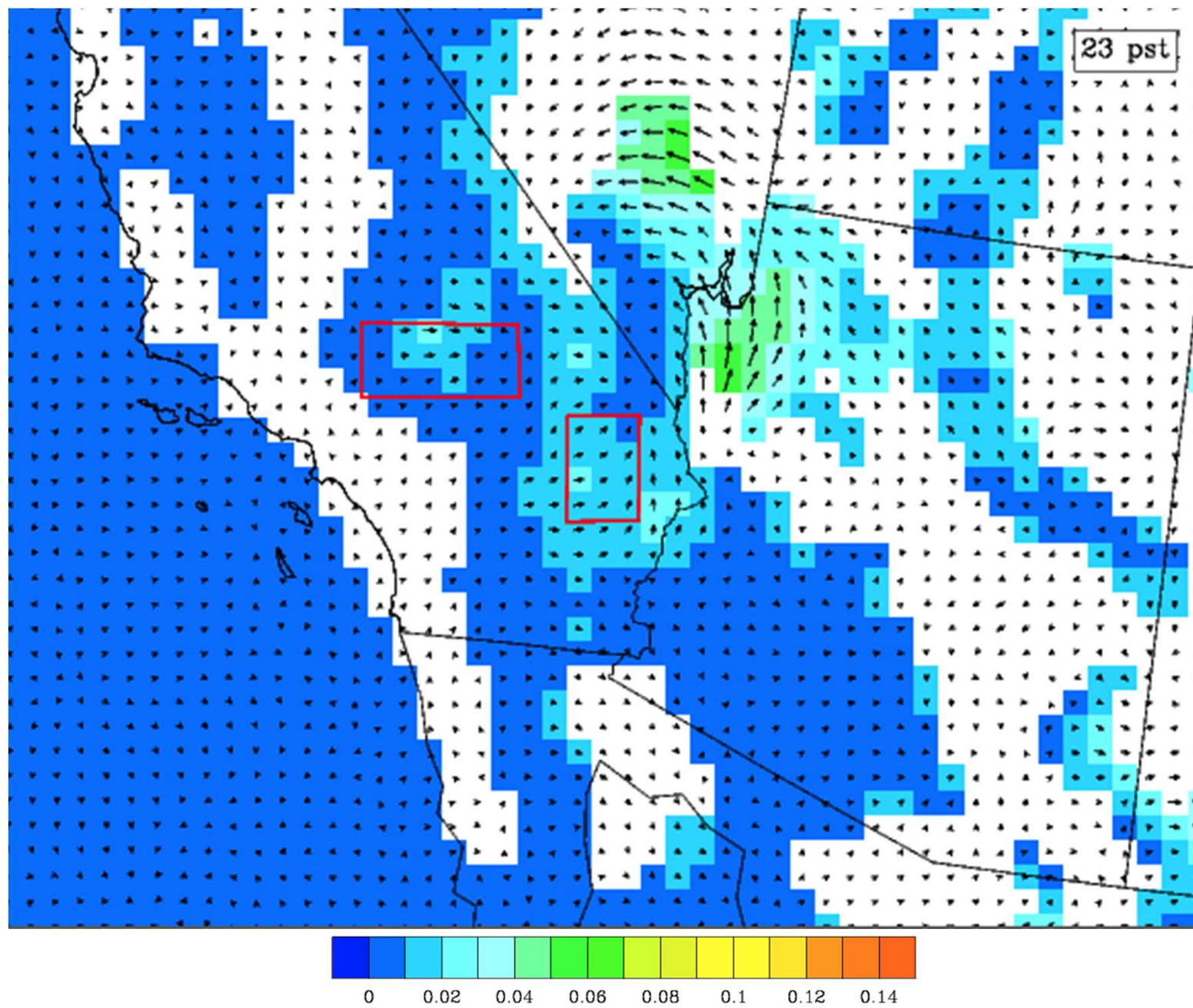


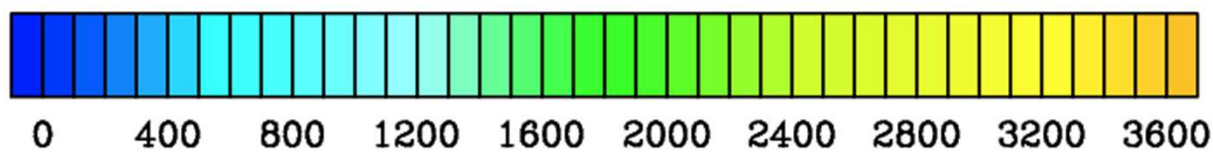
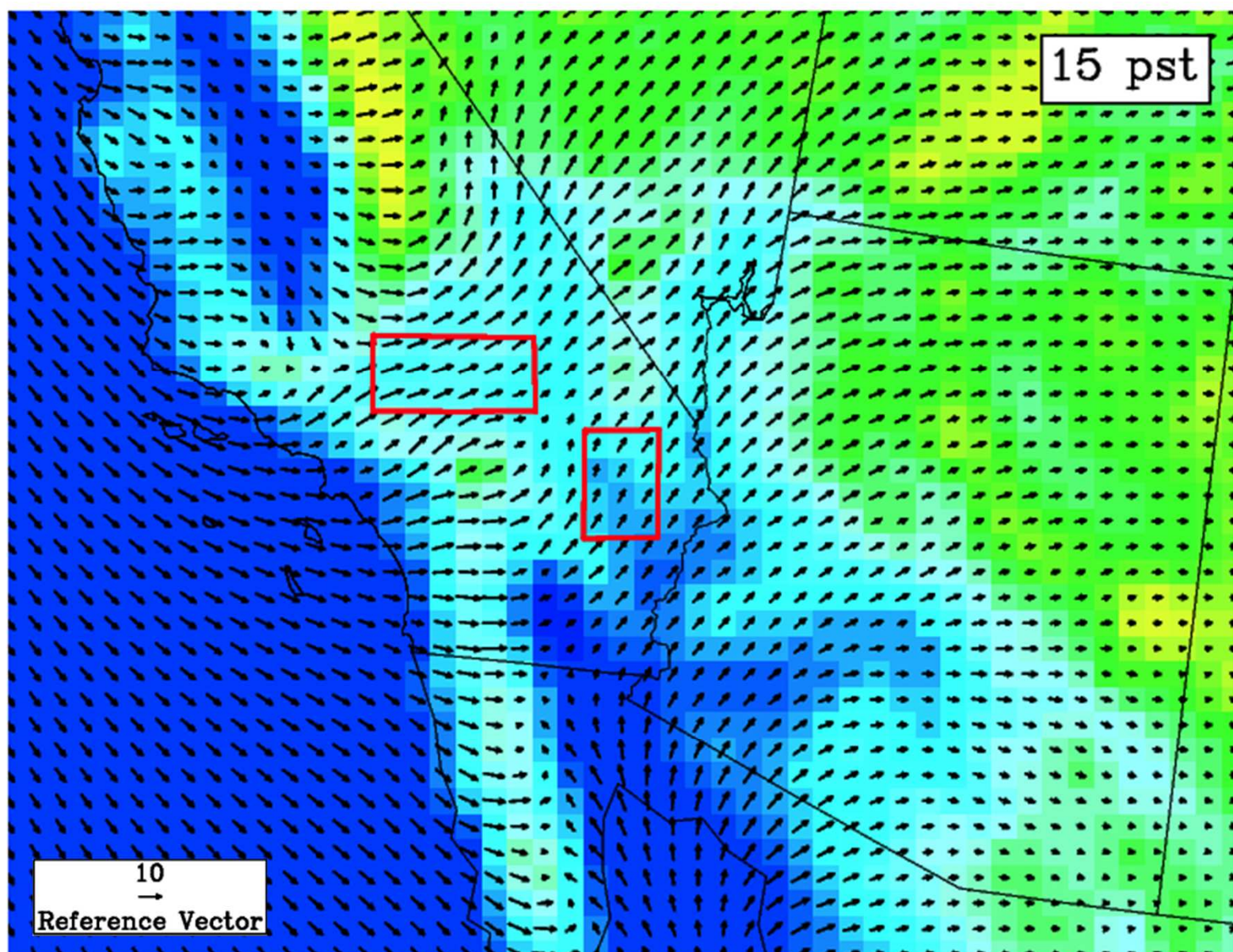




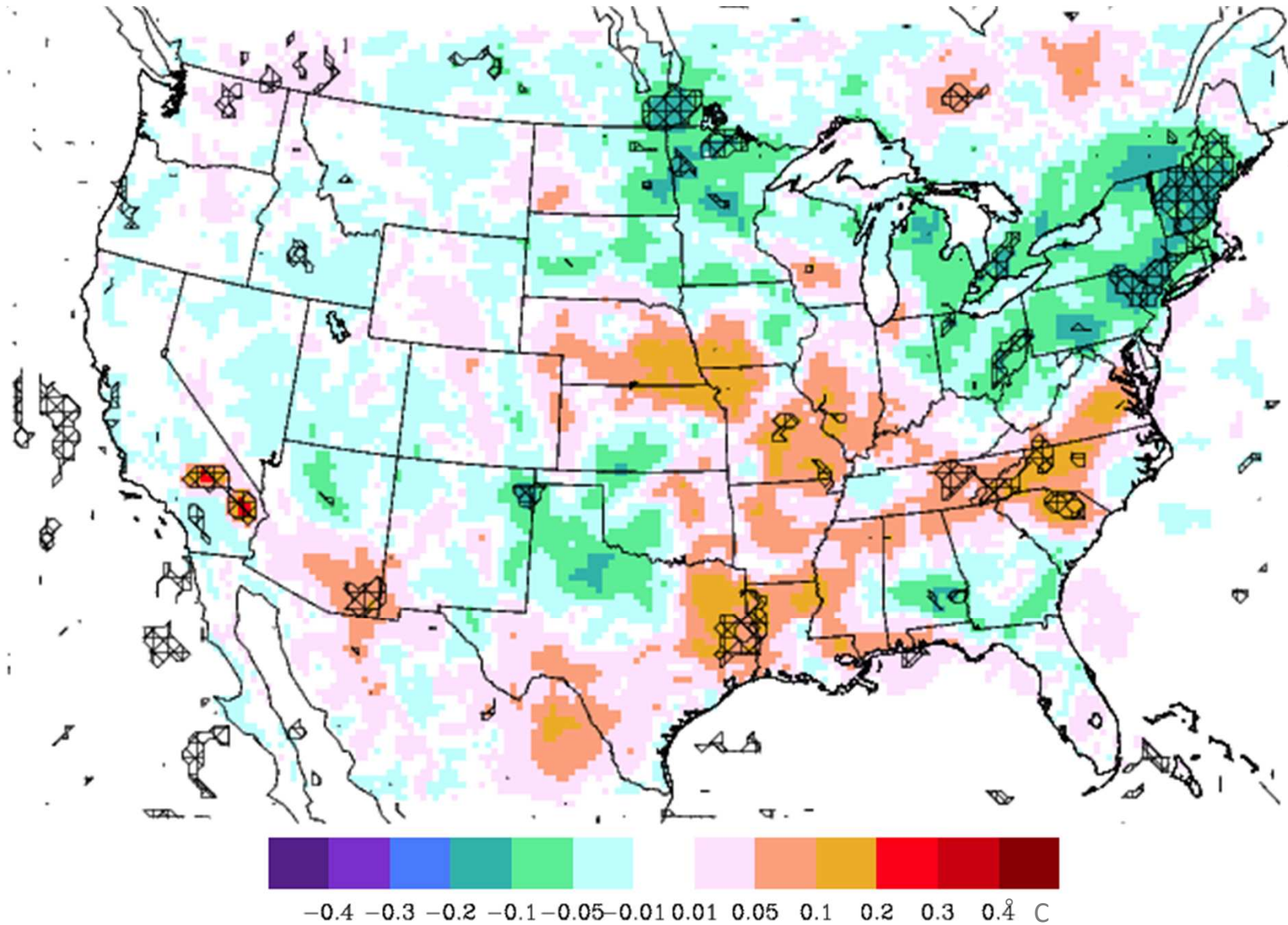








Temperature change from PV



Summary

Cool Roofs

- Increased urban albedo leads to significant cooling
- Coupled land-atmosphere modeling demonstrates regional differences due to albedo changes
- No urban areas see average warming
 - A few cities do not see average cooling
- CO₂ offset, 3.3 Gt (175 kg / m² roof)

Photovoltaic Power

- Temperature and weather effects – 10² km
- Continental scale, year-to-year variability high